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STATIC STABILITY OF SEAPLANE FLOATS AND HULLS.

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One of the important factors in seaplane design is the stability at rest on the water. Ordinarily this is secured by basing a new design on the proportions followed in some old and successful design. Sufficient data has been compiled from various sources to clear up this point in each of the cases requiring study. These cases are lateral and longitudinal stability of twin floats, longitudinal stability of single floats, and lateral stability where wing tip floats are used (as with a single main float or boat hull). The longitudinal stability of boat hulls is so great that it may be neglected.

The method followed in the case of single and twin floats is to obtain a satisfactory approximation to the metacentric height and study the values actually used in successful designs.

LATERAL STABILITY - TWIN FLOATS.

The lateral metacentric height of twin floats is readily approximated by use of the conventional formula of Naval Architecture. Referring to Figure 1, and to any work on Naval Architecture

$$BM = \frac{I}{V}$$

where I is the moment of inertia of the waterplane area and V

the volume of displacement. Let s be the spacing of the floats on center lines, L the length, and b the beam of each float. Then, assuming the area of the waterplane for each float to be Lb, the moment of inertia of the total waterplane area is

$$I = \frac{L}{12}\left((s + b)^3 - (s - b)^3\right)$$

$$= \frac{L}{12}(6s^2 b + 2b^3)$$

The weight of one cubic foot of sea water is 64 lb. Therefore, the volume displaced is

$$V = \frac{W}{64}$$

where W is the gross weight of the seaplane in pounds. Combining the expressions for I and V:

$$BM = \frac{64L}{12W}(6s^2b + 2b^3)$$

The metacentric height GM is then given by

$$GM = BM - BG = \frac{64L}{12W}(6s^2b + 2b^3) - h$$

where h is the distance of the c.g. above the c.b.

This formula is not exact in that it assumes the waterplane area to be rectangular. It appears, however, upon study of the formula, that a further approximation might be made in neglecting the terms $2b^3$ and h, and attempting to allow for all approximations by the use of a single constant, whose value is determined by calculation or by experiment. That is

$$GM = \frac{K_1 \, L s^2 b}{\Delta}$$

where Δ is the gross displacement in pounds.

The value of K_1 has been determined from a series of tests at the Washington Navy Yard Experimental Model Basin, and found to be remarkably constant with a value of 19.5 as shown by Table I. The application of this formula to full scale in design will be discussed later.

LONGITUDINAL STABILITY - SINGLE AND TWIN FLOATS.

Following the method used to determine the lateral metacentric height, it will be assumed that the waterplane area of each float is rectangular and of area $L \times b$, so that the moment of inertia of the total waterplane area is

$$I = \frac{n}{12} \, b L^3$$

where n is the number of floats. This gives

$$GM = \frac{64 n b L^3}{12 \, \Delta} - h$$

or simplifying

$$GM = \frac{K_2 n b L^3}{\Delta}$$

The value of K_2 has also been determined from a series of inclining tests and found to have an average value of

$$K_2 = 2.10$$

as shown by Table II. Individual values vary more from the average for K_2 than for K_1 owing to the deviations in the con-

tour of the waterplane area which affect the length more than the breadth, and the value of K_2 depends upon the cube of the length while the value of K_1 depends directly on the length. Allowing for probable errors in measurement, it appears that the approximate formula for longitudinal metacentric height will give results within 10% when K_2 is taken as 3.10.

LATERAL STABILITY - SINGLE FLOAT AND BOAT TYPE SEAPLANES.

Single float and boat type seaplanes require the use of auxiliary floats on the wing tips to secure lateral stability. In this case it seems advisable to make use of direct righting moments rather than metacentric heights. The wing tip floats are attached at a distance l, from the plane of symmetry, and requires a lateral inclination of θ degrees before submergence. When just submerged a wing tip float, displacing Δ pounds, exerts a righting moment of

$$L_1 = \Delta l \cos \theta \text{ lb.ft.}$$

The disturbing moment due to the lateral inclination is

$$L_2 = Wh \sin \theta \text{ lb.ft.}$$

where W is the gross weight of the seaplane and h the distance of the c.g. above the c.b.

L_1 must be sufficiently greater than L_2 to allow for all additional disturbing moments such as the effect of side wind on the fuselage or on a yawed wing with dihedral. These moments have been calculated for several representative cases and found

to be small in comparison with the moment due to inclination. It
should therefore be allowable to put

$$L_1 = C\ L_2$$

$$\text{or}\quad \Delta\ l\ \cos\theta = C\ Wh\ \sin\theta$$

and determine the value of C corresponding to satisfactory (and
unsatisfactory) designs. This has been done for the seaplanes
listed in Table III, and it is found that C varies from 1.4 to
5.7. One design, the VE-7 seaplane, having a value of C = 1.33,
was unsatisfactory. Doubling the displacement of the wing tip
float so that C = 2.67, resulted in satisfactory stability.
In view of the performance of the various seaplanes tabulated in
Table III, it is to be concluded that satisfactory lateral sta-
bility will be obtained when C = 2.00.

APPLICATION TO DESIGN.

Values of lateral and longitudinal metacentric heights for
various seaplanes have been calculated by means of the approximate
formulae just derived. The data are given in Table IV. Upon
plotting these metacentric heights against the corresponding
gross weights, as in Figs. 2 and 3, it appears that the metacen-
tric height is approximately a straight line function of the gross
weight. For the lateral metacentric height

$$GM = 13 + .002\ W$$

and for the longitudinal metacentric height

$$GM = 15 + .002 \; W$$

GM being in feet and the gross weight W in pounds.

Obviously the values given by these two lines are by no means final. They are based on a small number of designs and refer to approximate values for these designs. It is thought, however, that the values so indicated are a reliable guide to current practice. Changes may be made as found desirable when more data have been accumulated.

It is recommended that the longitudinal and lateral metacentric heights be made equal and of the value given by

$$GM = 15 + .002 \; W$$

The proper length or spacing required to satisfy the indicated value may then be obtained from substitution in the approximate formulae for metacentric height.

· TABLE I.

LATERAL STABILITY OF TWIN FLOATS FOR SEAPLANES.

DETERMINATION OF K_1 IN THE FORMULA

$$GM = \frac{K_1 Lbs^2}{\Delta}$$

MODEL TEST DATA.

Model	Length L ft.	Beam b ft.	Spacing on ₵ s ft.	Dis-place-ment Δ lb.	Meta-centric height GM ft.	$\frac{Lbs^2}{\Delta}$	K_1
Loening	2.33	.292	.875	4.67	2.119	.1117	19.0
CT	2.083	.348	1.000	6.07	2.328	.1192	19.5
"	2.083	.348	1.000	5.08	2.97	.1423	20.9
"	2.083	.348	1.000	4.35	3.17	.1663	19.1
"	2.083	.348	1.000	3.63	4.01	.1993	20.1
"	2.083	.348	1.000	2.72	5.06	.2660	19.0
TS-1	1.832	.241	.777	2.71	1.955	.0983	19.9
DT	2.045	.296	.833	3.94	1.890	.1067	17:7
SS	1.75	.245	.791	2.61	2.030	.1028	19.8
VT	1.748	.244	.803	2.63	2.015	.1048	19.2
VT-1	1.83	.244	.803	2.63	2.29	.1097	20.8

Average 19.5

TABLE II.

LONGITUDINAL STABILITY OF SEAPLANE FLOATS.

DETERMINATION OF K_2 IN THE FORMULA

$$GM = \frac{K_2 nbL^3}{\Delta}$$

MODEL TEST DATA.

Model	Length L ft.	Beam b ft.	Number of floats n	Displacement Δ lb.	Metacentric height GM ft.	$\frac{nbL^3}{\Delta}$	K_2
Loening	2.33	.292	2	4.67	3.164	1.58	2.00
"	2.31	.249	2	4.90	2.614	1.253	2.08
CT	2.083	.348	2	6.07	2.053	1.034	1.99
"	2.083	.348	2	5.08	2.90	1.237	2.34
"	2.083	.348	2	4.35	3.47	1.443	2.40
"	2.083	.348	2	3.63	3.59	1.730	2.07
"	2.083	.348	2	2.72	4.14	2.310	1.79
TS-1	1.832	.241	2	2.71	2.360	1.093	2.16
DT	2.045	.296	2	3.94	2.423	1.284	1.89
WA	2.09	.271	1	2.37	2.196	1.043	2.10
SS	1.75	.245	2	2.61	2.414	1.006	2.40
TG	2.36	.361	1	3.75	2.482	1.265	1.96
VT	1.748	.244	2	2.63	2.395	0.39	2.40
VE-1	1.83	.244	2	2.63	2.270	1.14	1.99
NC	3.133	.699	1	9.35	4.18	2.295	1.82

Average 2.10

TABLE III.

LATERAL STABILITY SEAPLANES WITH WING TIP FLOATS.

Seaplane	Gross weight W lb.	Displacement each wing tip float Δ lb.	c.g. above c.b. h ft.	Wing tip float to ₵ l. ft.	Angle to submerge wing tip float θ°	tan θ	C	Remarks
N9	2400	160	5.7	19.1	9	.158	1.42	
HS-2	6430	275	4.9	26.4	7	.123	1.87	
HS-3	6430	680	4.5	26.4	7	.123	5.03	
H-16	10900	1170	6.0	30.4	8	.140	3.88	
F-5-L	13500	1175	6.0	33.2	7	.123	3.92	
NC	22000	1800	7.5	41.5	4.5	.079	5.70	
MF	2490	160	4.0	15.6	10	.176	1.43	
TF	8850	1000	5.0	20.5	9	.158	3.23	
VE-7	2600	190	6.0	13.5	7	.123	1.33	Unsatis-
VE-7	2600	380	6.0	13.5	7	.123	2.67	fac-
Mod.40	2467	265	4.3	14.75	10	.176	2.08	tory
HA	3910	290	5.0	14.3	7	.123	1.72	

TABLE IV.

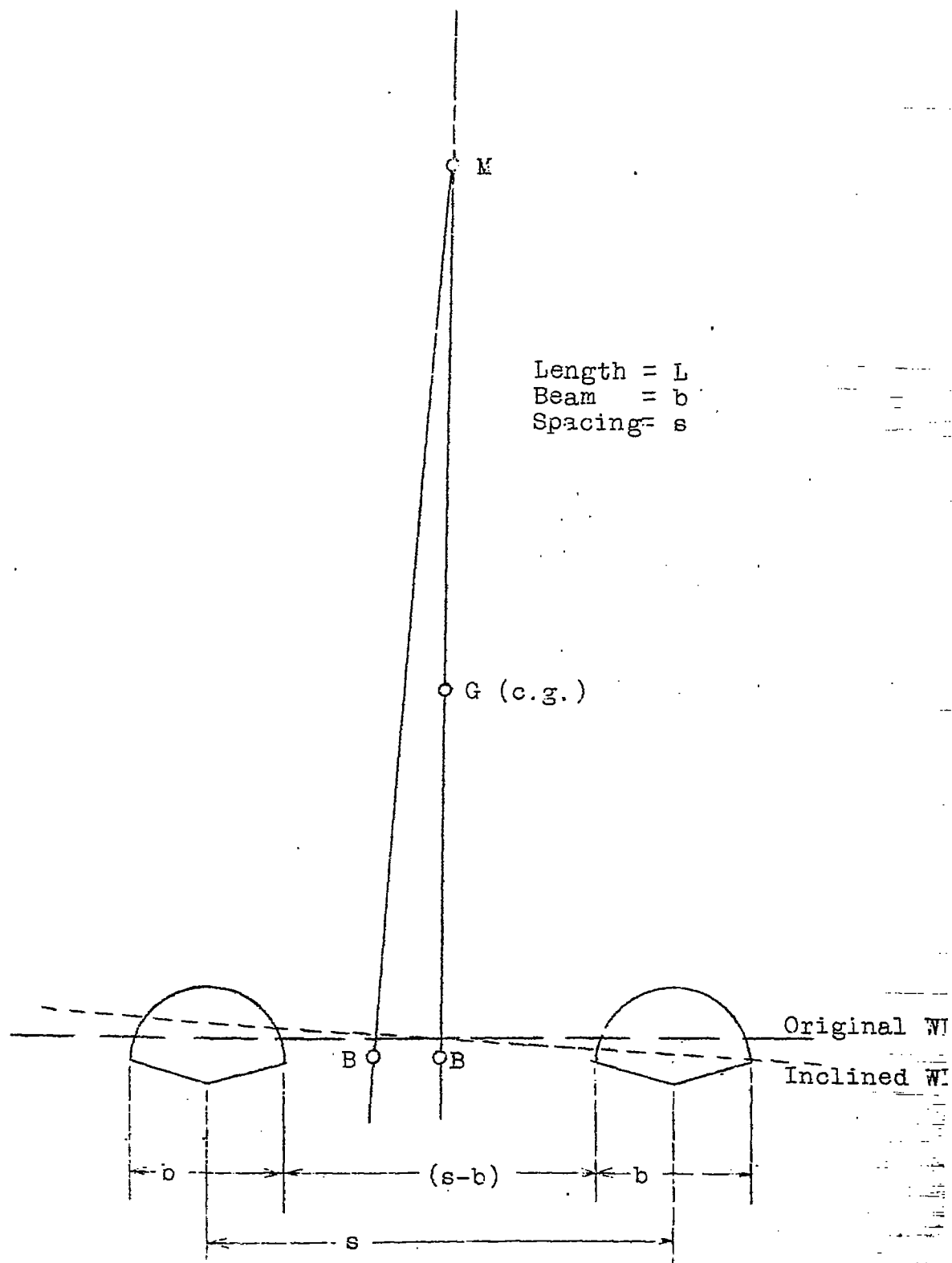### FULL SCALE METACENTRIC HEIGHT OF SEAPLANES.

(CALCULATED BY FORMULA)

Seaplane	Dis-placement Δ lb.	Length of boat L ft.	Beam b ft.	Number of floats n	Spacing on ₵ s ft.	Longitu-dinal GM ft.	Lateral GM ft.
Loening	2450	18.67	2.33	2	7.0	26.0	17.0
CT	10000	25.00	4.7	2	12.0	27.4	29.3
TS-1	2025	16.50	2.18	2	7.0	20.3	17.0
DT	6975	24.53	3.55	2	10.0	31.6	24.3
SS	4615	21.0	2.93	2	9.0	24.8	20.9
VT	8615	25.75	3.61	2	11.83	29.9	29.4
R6	3950	20.0	2.50	2	11.0	21.3	29.8
Boeing	2455	16.0	2.28	2	7.5	16.0	16.4
WA	4200	25.06	3.25	1	–	25.6	–
TG	2800	21.25	3.25	1	–	23.3	–
N9	2400	17.83	3.48	1	–	17.3	–
NC	22000	44.8	10.0	1	–	86.0	–
GB	65000	64.86	14.6	1	–	129.0	–

Lateral metacentric height: $GM = \dfrac{19.5 \ Lbs^2}{\Delta}$

Longitudinal metacentric height: $GM = \dfrac{2.10 \ nbL^3}{\Delta}$

Fig.1

Length = L
Beam = b
Spacing= s

M

G (c.g.)

Original WI

Inclined WI

B   B

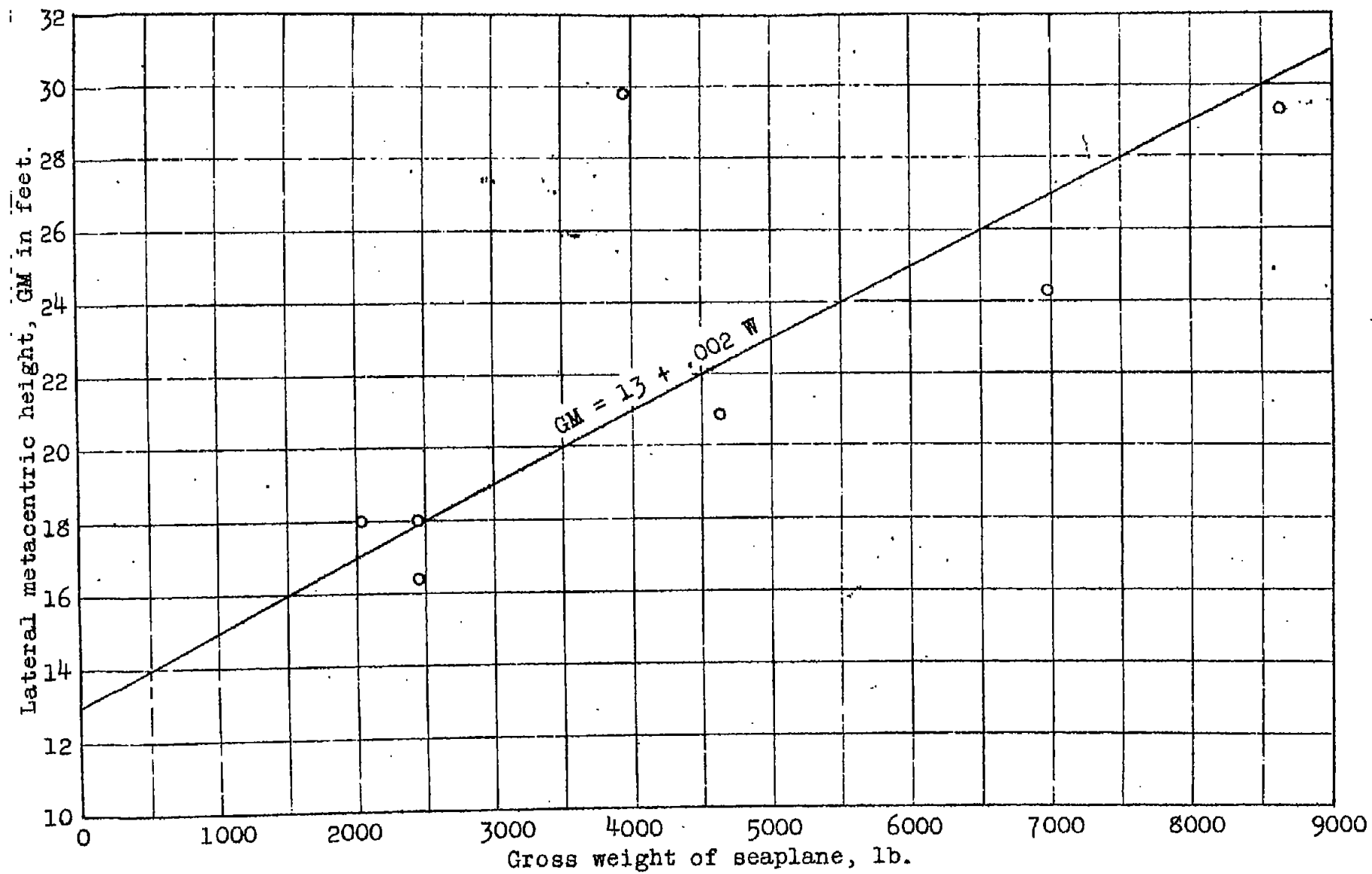|← b →| (s-b) |← b →|

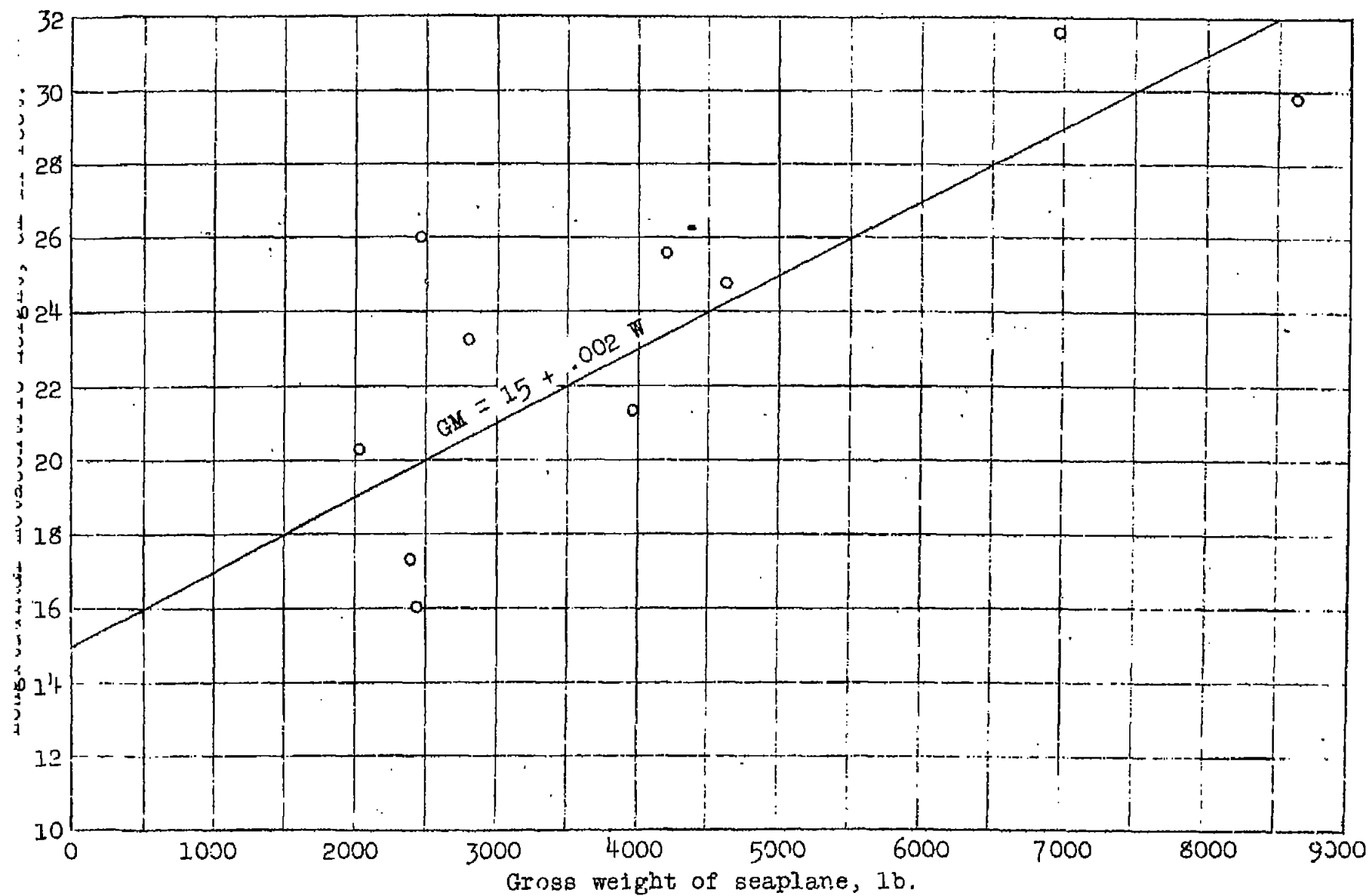|←   s   →|

Fig.2 Lateral metacentric height of twin float seaplanes.

Fig. 3   Longitudinal metacentric height of single and twin float seaplanes.